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Fluorite Near Silver Bow, Montana

Charles V. Campbell

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A Thesis
Submitted to the Department of Geology
in Partial Fulfillment of the Requirements
for the Degree of Bachelor of Science
in Geological Engineering

Montana School of Mines
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ABSTRACT

The wartime demand for fluorspar has caused renewed interest in fluorite deposits. Near Silver Bow, Montana, a deposit of massive, coarsely crystalline fluorspar, which has not been described in the literature, has attracted the attention of the United States Geological Survey.

Fluorite associated with chalcedonic quartz occurs (1) as a fissure filling and (2) as the cementing material of a very loose, coarse breccia. This deposit is believed to be associated with hot spring action and is of the epithermal type of deposit.

Present development and surface exposures indicate that, although the grade is satisfactory, tonnages available are inadequate for commercial expolitation.

INTRODUCTION

Vital in the present war effort is the mineral, fluorite, which is used in refining steel. Special effort has been made by the United States Geological Survey to discover new deposits of this mineral, and most of the mining districts have been re-examined in view of the occurrence of possible commercial deposits of fluorspar.

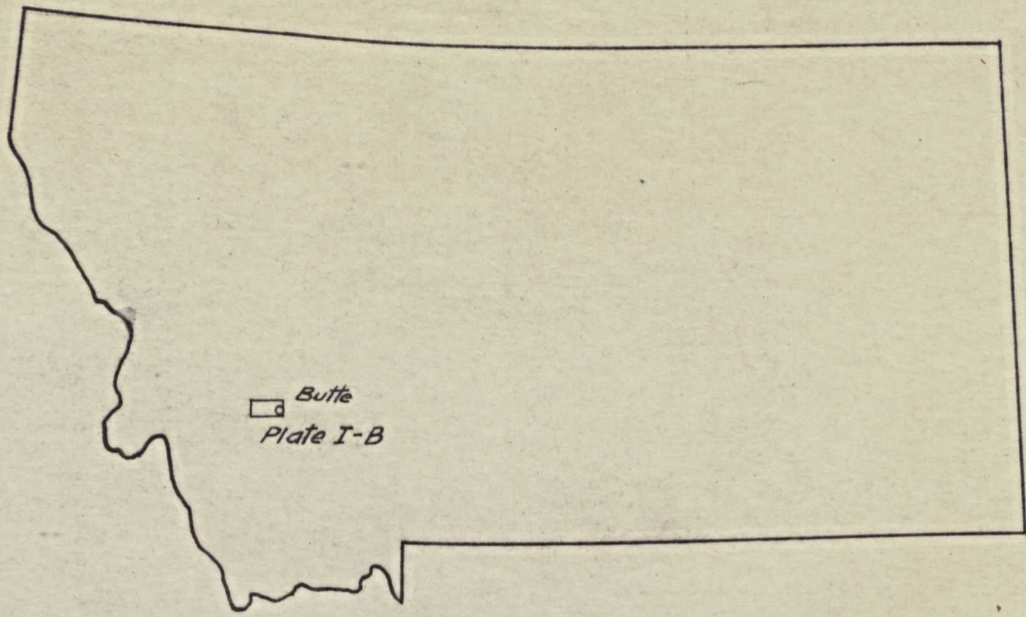
Near Silver Bow, Montana, at the western margin of the Boulder batholith is a deposit of fluorite, which has not been described in the literature. This report is primarily concerned with the geology of that ore deposit. To be determined are the mode of occurrence and the manner of origin of the fluorspar along with the possibilities of commercial exploitation and other related features as the local structure and alterations.

The area in question is about three-quarters of a mile square and lies immediately north of U.S. Highway 10 between Silver Bow and Nissler Junction, Montana, and is five and one-half miles west of that famous copper mining camp, Butte, Montana. It occupies parts of sections 13 and 18, township 3 north, ranges 9 and 8 west. See Plates I and IV.

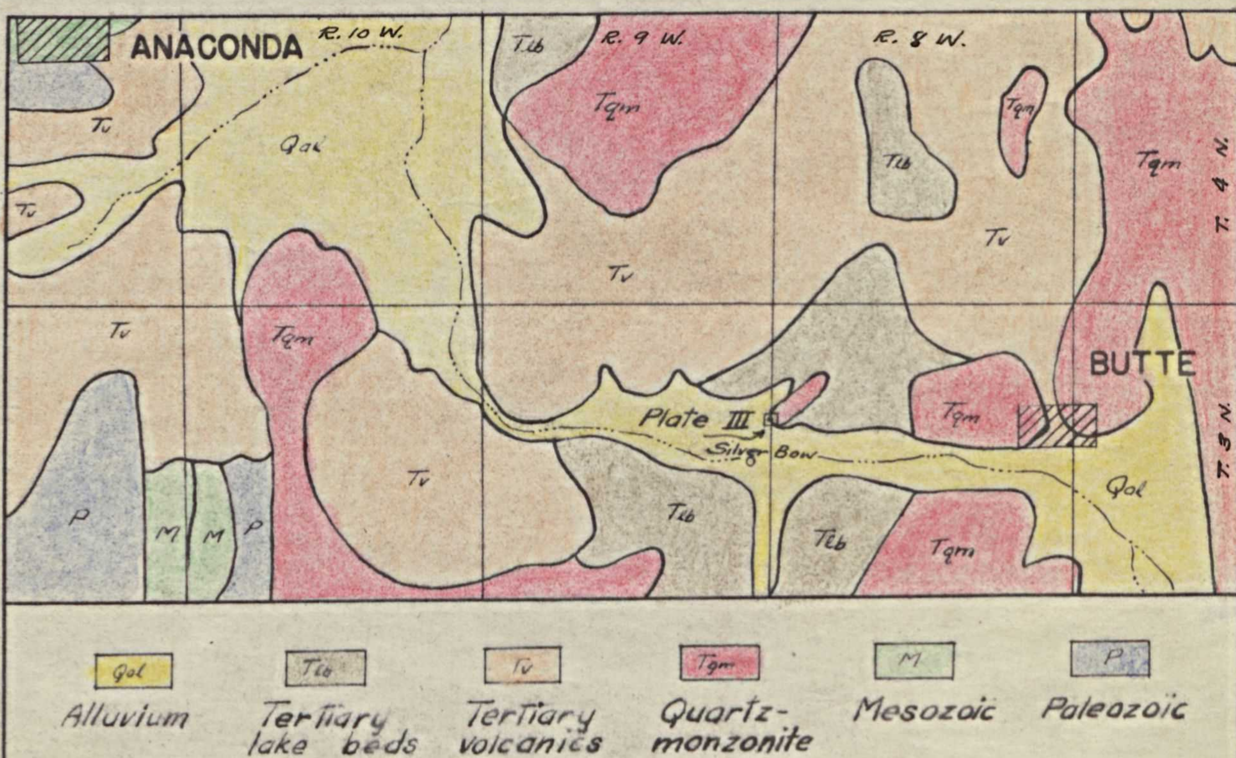
Previous to last year little or no prospecting had been done on this fluorite deposit. Recently, however, several pits have been dug on the veins; and at the present time an adit is being driven in the general direction of the fluorspar veins from a nearby pit. Several shafts and numerous trenches have been dug in the surrounding area; but all such excavations were on massive, milky, glassy quartz veins, apparently in search of gold. Many such pits are indicated on the geologic map of the area studied.

Methods of study included the making of plane table maps of the area in general, and of the vein in particular. Distances were measured by pacing, but all points were tied into general Land Office township plats. Many specimens were collected with accompanying field notes. In the laboratory many thin sections of rocks in that area were made and examined with the petrographic microscope, and the minerals were also studied by crushing and immersing in oils of known refractive indices. Field work was done in the late summer months of 1943.

The writer takes pleasure in acknowledging the assistance of Dr. E.S. Perry whose suggestions and guidance proved invaluable to the successful comprehension and completion of the problem at hand. To Dr. W.W. Swayne of the Anaconda Copper Mining Company's geology department the author expresses his thanks for



A. INDEX MAP SHOWING LOCATION OF FLUORITE DEPOSIT



GEOLOGIC MAP
of area between
BUTTE and ANACONDA
(after Mont. Bur. Mines and Geol.)

B.

the aid and advice tendered relative to both field and petrographic problems, and suggestions made by Dr. L.L. Sloss proved of great value in compiling this report.

FLUORITE, CHARACTERISTICS AND OCCURRENCES

Fluorite (CaF_2), the only common, simple fluoride occurring in nature, crystallizes with cubic habit in the isometric system. Twinned cubes are not uncommon, and rare but characteristic are other forms such as hexoctahedrons and tetrahexahedrons. Also massive, compact, coarse to fine granular, or columnar fluorite is found; and a dull, earthy type is not uncommonly associated with gold tellurides. Perfect octahedral, (111), cleavage is exhibited by this mineral.

A relatively soft and light mineral, fluorite has a hardness of 4 on Mohs scale of hardness and a specific gravity of 3.18-3.25. Fluorite is transparent to translucent with a vitreous luster. Color, which helps to distinguish this mineral, is most commonly green, purple and white; but bluish-green, colorless, rose, blue and brown fluorite are found. The massive variety commonly shows delicate banding in color. A refractive index of 1.4339 for this mineral is the lowest of any of the common minerals, and some varieties of fluorite show the phenomenon of fluorescence.

Fluorite occurs under widely varying conditions. Most commonly it is found in veins either as the chief constituent or a gangue associated, especially, with galena but also with silver and zinc minerals. Other associated minerals are quartz, calcite and barite. Fluorite is described as being characteristic of pneumatolytic deposits, especially those carrying tin where typical associations are topaz, tourmaline and apatite. In sedimentary rocks as limestones and dolomites fluorite may occur in quantity, and it is a minor accessory in some igneous rocks such as granites. Another mode of occurrence of fluorite described is as a sublimation product in connection with volcanic rocks.

Fluorite is a mineral of wide distribution, but deposits extensive enough to be commercial are relatively few. Most of the United States production comes from southern Illinois and adjacent parts of western Kentucky. Minor amounts come from Colorado, New Mexico, Arizona, Utah and New Hampshire. England, Germany and Russia are the major foreign sources of fluorite.

In southern Illinois at Rosiclare the fluorite fills fault fissures in Carboniferous limestones and sandstones, and in some places the veins are forty-five feet in width. Associated with the fluorite in the veins are calcite and small amounts of the sulphides of lead and zinc. Horizontal masses of fluorspar averaging four feet in width, believed to be replacements of limestone, are found in the Cave in Rock area of Illinois. Mica peridotite dikes are found in both places but are not in contact with the fluorspar. The origin of those deposits is doubtful; but they may be of magmatic origin[1], replacements of vein calcite[2], or derived from heated waters, either magmatic or meteoric, which leached the minerals from some large mass of low-lying igneous rocks of which the dikes are off-shoots[3].

Similar to the Illinois fluorspar is the occurrence of fluorite in western Kentucky. There the mineral is found in veins in fault fissures that cut Carboniferous limestones, sandstones and shales; the minerals have been deposited by filling fissure

[1]Spurr, Eng. Min. Jour., CXXII, 968, 1926
[2]Currier, Ky. Geol. Surv., Ser. 6, XIII, 1923
[3]Bain, U.S. Geol. Surv., Bull. 255, 1905

cavities, replacing the wall rock of the fissure, or as a breccia cement. Common associations are barite, calcite, galena and sphalerite. The origin of the deposit is believed to have been from thermal waters which were given off from a deep-seated magma during the cooling of the peridotite dikes that are found in the surrounding region.

Colorado fluorspar is produced mostly in three localities. At Wagon Wheel Gap in Mineral County fluorite occurs in fissure veins that follow zones of sheeted rhyolite, and are more or less parallel to the walls of the rhyolite zone. Pyrite, barite, quartz, calcite and kaolinite are associated minerals. The average width of the veins is four feet, but the width ranges from a few inches to thirty-five feet, and active hot springs are associated with the fissures. Mamillary fluorite and well crystallized barite suggest that deposition took place in open spaces.

Characteristically dark purple fluorite associated with pyrite and galena is found in two to four feet veins at Jamestown in Boulder County. There the coarsely crystalline fluorspar, containing siliceous impurities, occupies a fissure in granite country rock. A single vein, at times branching into a series of parallel veins ranging from a few inches to five feet wide, is found a North Gate in Jackson County. Gangue minerals are siliceous and carry some pyrite; the country rock is granite.

Catron, Grant, Luna, Sierra and Valencia counties in New Mexico are sites of the major fluorite deposits of that state. The occurrence of the fluorspar as vein fillings in igneous and sedimentary rocks or as replacements in limestone is the rule. The walls are not commonly well defined and are usually silicified. Those deposits are believed to be of magmatic origin and associated with Tertiary volcanic activity.

Small deposits in Arizona are in veins filling fissures in volcanic rocks, and Nevada production comes from fissure veins in dark-gray limestone that has been intruded by rhyolite. Fissures in limestone or pre-Cambrian gneisses near basalt or pegmatite dikes yield Utah's minor quantity of fluorite. The New Hampshire deposits consist of veins in granite country rock.

In the Tertiary volcanics south of Anaconda a deposit of fluorite is reported and is said to be much more extensive than the one herein described. Fluorite occurs in many localities in Montana, and among them are deposits near Helena, Missoula, Lewistown, in the Sweetgrass Hills and the Little Rocky Mountains. No deposit as yet has been found to be commercial in grade and size.

Many and varied are the uses of fluorite. The principal use is as a flux in the open hearth process for making steel where fluorite serves to reduce the freezing point of the slag, which makes a fluid slag at a lower temperature. Hydrofluoric acid is also prepared from this mineral; and a small quantity is used in the manufacture of opalescent, opaque and colored glass and in preparing enamel for cooking utensils. Very rare optical fluorite is used in lenses to correct spherical and chromatic aberration and in the prisms transparent to ultra-violet and infra-red light necessary in the spectrograph.

A. Landscape looking east at ridge crossed by the fluorite vein. The vein is along the line of rugged outcrops which form a breccia zone.

B. View of the breccia in the breccia zone shown in A. The light gray area at the right is fault gouge.

GEOGRAPHY OF THE SILVER BOW AREA

Topography of the area including the fluorite deposit is sharply rolling, as is typical of the region surrounding Butte to the west. It is believed to be a Tertiary peneplane which has been cut by many stream valleys. These streams carry water only after infrequent rain storms and during the spring thaw.

The maximum relief of the vicinity mapped approaches 200 feet above the level of Silver Bow Creek which marks the southern border of the region in question. To the west is a broad valley filled with lake beds, which extends southward thirty miles to Divide, Montana. Progressing from the lake beds to the east are low, somewhat rolling hills which are usually topped by desolate appearing masses of jointed or sheeted boulders. The black color, formed on the surfaces of those outcrops by weathering and oxidation by sulfurous fumes from smelters at Butte in a bygone day, tends to add to the bleakness of the landscape. Oxidation of iron minerals in the many quartz veins cutting the region has in some places imparted an iron-red color to the soil; and pink blotches on hillsides are commonly due to masses of aplite that have weathered from one of the many aplite dikes cutting the area.

A prominent feature of the topography of the area is the outcrop of the resistant quartz veins which shed quartz boulders on the downhill side of the lodes. More important, however, is the exposure of a silicified breccia which marks the contact zone. That resistant material forms bold, deep-red crags adjacent to the valley to the west. See Plate II.

Vegetation is scant and the yellowish-brown soil gives the area a dull, drab appearance. A sparse covering of hardy range grasses is found everywhere. Usually sage brush occurs in scattered clumps with occasional scrub junipers spotted about.

The climate is of the semi-arid type typical of the higher parts of the northern Rockies. Between 100 and minus 50 degrees Fahrenhiet the temperature ranges, and the annual mean is about 43 degrees. The annual rainfall approaches fifteen inches.

Along the margin of Silver Bow Creek and the southern side of the area studied is U.S. Highway 10 from which a side road traverses the one-eighth mile to the vicinity of the fluorite vein. See the geologic map, Plate IV. Four railroads, the Union Pacific, the Northern Pacific, the Chicago, Milwaukee, St. Paul and Pacific, and the local Butte, Anaconda and Pacific, border Silver Bow Creek and pass through the area surveyed. The Union Pacific railroad has a station at Silver Bow less than one-half mile from the deposit.

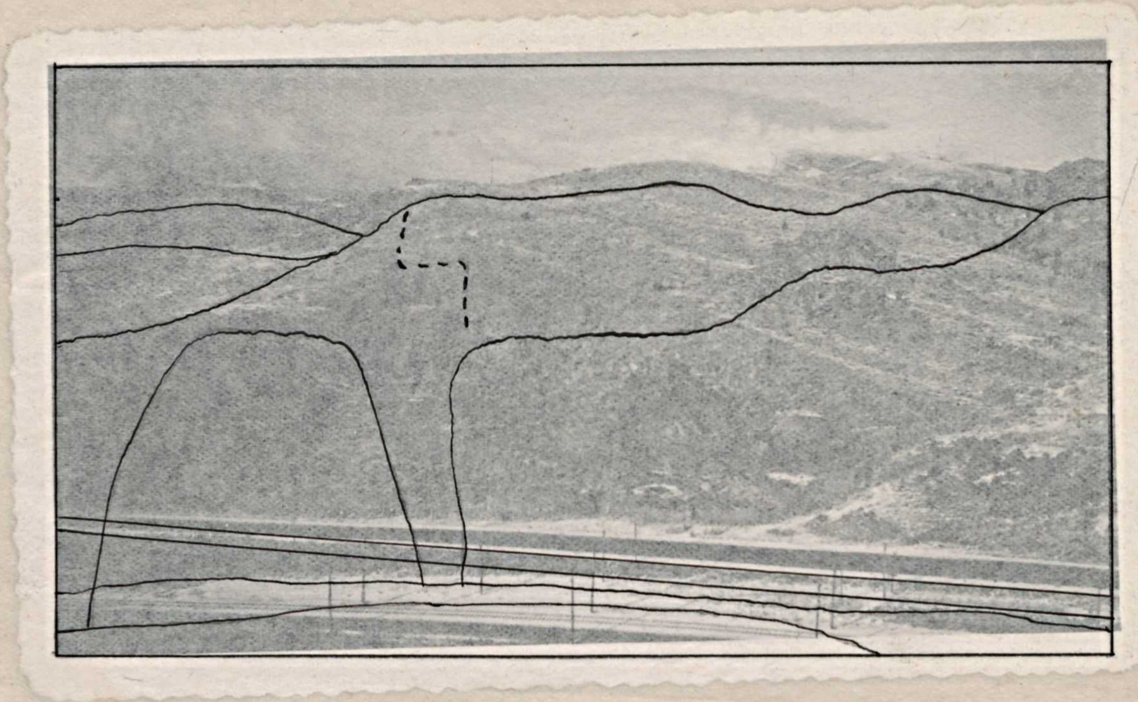
GENERAL GEOLOGY OF THE SILVER BOW AREA

Summary of the General Geology

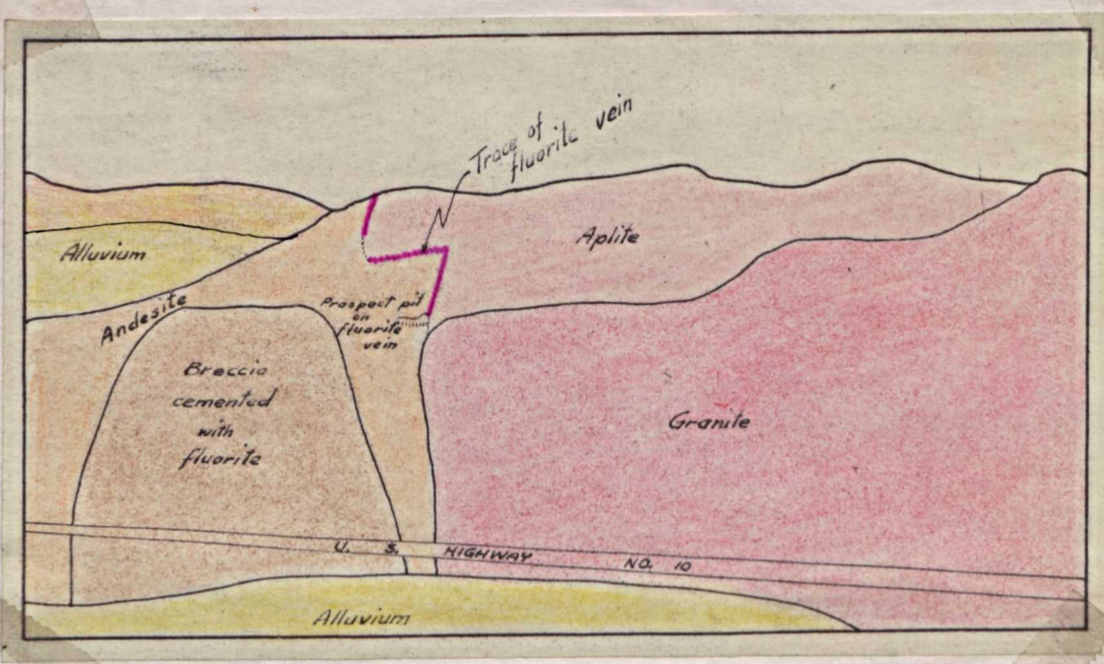
The general geology of the Silver Bow area is similar to that of the surrounding Butte region. Alluvium and lake beds encircle the small exposure of igneous rocks on the west border of which lies the fluorite deposit. See Plate I-B. That intrusive igneous body is essentially quartz-monzonite, altered in varying degrees, and it is cut by aplite dikes or contains aplite seggregations of irregular shape. A small area of andesite was mapped adjacent to the contact. The alluvium near the contact is deep-red in color due to the disintegration of the andesite, and fragments of vein quartz make up a significant part of the weathered debris. A good exposure of the lake beds was not found in the area traversed due to recent coverings by alluvium; and, for that reason, the two types of sedimentary material were mapped as a unit. Aerial distribution of the rocks is shown in Plates III-B and IV.

The areas of highly altered quartz-monzonite are cut by networks of veins of varying size, and several periods of fissuring and mineralization are evidenced.

Since the fluorite deposit is associated with rocks of the Boulder batholith, the geologic history closely follows that of the igneous mass as well as that of the Butte mining district. Prior to the Laramide orogeny at the end of the Cretaceous period the normal series of Paleozoic and Mesozoic sediments overlay the present Butte area, and the uppermost formation was a great thickness of andesitic volcanics. Early in the Laramide orogeny these rocks were folded into a broad synclinorium into which the



A.—Landscape looking north and showing mineralized area



B. Sketch showing geologic features in A batholith was intruded with no apparent doming effect. The fact that the rocks get progressively older, Mesozoic, Paleozoic and pre-Cambrian, as one proceeds away from the plutonic body in any direction suggests a synclinal structure.

The mass of the igneous body was quartz-monzonite; but on cooling large irregular masses of aplite, possibly representing an acid phase of the magma, segregated out. Additional acidic emanations filled fissures in the cooling quartz-monzonite forming aplite dikes. Both types of rocks are found in the vicinity of the fluorite vein.

Fissuring and mineralization in the central Butte region is believed to have occurred in early Eocene times, and many of the glassy quartz veins in the eastern part of the area surveyed probably originated at that time. Sometime after that period of mineralization the banded vein-type of fluorite described in this report was precipitated on the walls of a north trending fissure. Further faulting, nearly at right angles to the fluorite vein, then offset and shattered that vein. A silicified breccia containing fragments of fluorite is evidence of still further faulting, and streaks of that breccia now lie en echelon which indicates another period of faulting. More fluorite, whitish-gray in color, was deposited then as a breccia cement. Whether that fluorite is cementing a talus breccia or a breccia resulting from a previous fault cannot be definitely stated due to insufficient exposures.

Late in the period of deformation and mineralization another east-west trending fault, obscured by the alluvium covering the bottom lands of Silver Bow Creek, is believed to have developed. This fault is not known to be mineralized nor are any of the other east-west fissures that cut the fluorite vein.

Whether the last periods of faulting are pre- or post-lake bed age cannot be determined, due to the covering of alluvium over the lake beds in the surveyed area; nor can the age-relation of the stages of faulting to the long period of Eocene erosion followed by rhyolite flows be determined, since no rhyolite was found.

No evidence of recent glacial activity is found in the near vicinity of Butte so it is logical to assume that the area has been subject to erosion since earliest Tertiary times.

Petrology and Petrography

Both intrusive and extrusive igneous rocks are found in the Silver Bow area. The flow rock is an intensely altered andesite, and plutonic rocks are aplite and quartz-monzonite. The material resulting from the weathering of these rocks makes up the unlithified alluvium which in the western part of the area studied overlies lake beds. Poor exposures of the lake beds are found in the road cut north and east of Silver Bow.

Andesite--Exposures of the andesite are few, as it is in most places covered by alluvium; but one small area of that type of rock is shown on the geologic map of the area. Hand specimens show a porphyritic textured rock in which apparent white phenocrysts of feldspar are imbedded in a dense, hematite-red groundmass. The feldspars appear to be altered to kaolin.

Under the microscope the andesite is highly altered. The phenocrysts, which make up about forty percent of the original rock, are so highly altered and replaced that it is difficult to ascertain whether they were originally orthoclase or plagioclase.

No definite remnants of crystal faces were observed which might have given one a hint as to the original nature of the feldspars; in fact, the outlines of the phenocrysts were so ragged in most cases that they appeared to be filled vugs. Not only were the phenocrysts entirely kaolinized, but considerable chalcedony has been introduced, due to the proximity of the exposure of andesite to the silicified breccia zone described in a later section of this paper. Cryptocrystalline quartz was also observed in minute cracks and fissures which lead to the apparent phenocrysts.

About three percent of the rock is quartz which occurs in small subhedral crystals in the same manner as the larger phenocrysts. This quartz, moreover, shows little sign of alteration. The dense, hematite-red groundmass has the appearance of a devitrifying glass under the microscope and makes up about fifty-five percent of the total composition of the rock.

That the above described rock is extrusive is undoubted, but the author cannot definitely further classify it other than to say that its dark color indicates an andesite. Studies of that flow rock in other less altered areas have proved it to be andesite[1], and that name is the one herein used. These andesites are probably correlative to the late Cretaceous volcanics which are found at South Boulder Canyon and adjacent areas.

Quartz-monzonite--Quartz-monzonite, the most abundant rock of the Boulder batholith, is found throughout the eastern part of the area surveyed. Prominent outcrops of that rock rise in isolated mounds that are topped by large, joint blocks of "fresh" quartz-monzonite; and around these but little altered rocks one

[1]Weed, U.S. Geol. Surv., Prof. Paper 74, 1912, p. 27

finds intensely altered, easily eroded quartz-monzonite that is cut by numerous quartz-bearing veins.

Figure 1. Photomicrograph of quartz-monzonite showing hornblende (dark) altering to epidote. X 20

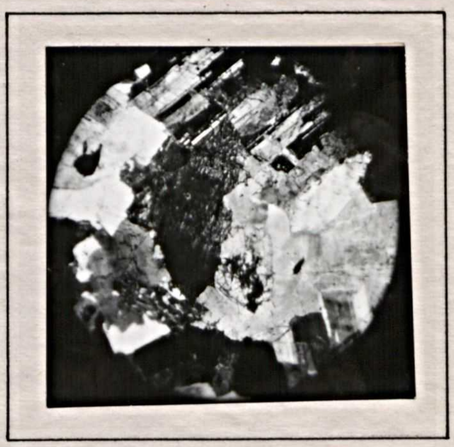


Figure 2. Photomicrograph showing quartz-monzonite of Figure 1 under crossed nicols. X 20

In hand specimens the "fresh" quartz-monzonite is a coarse, even-textured rock of a grayish-green color; but the more altered type is a mass of kaolin or sericite containing quartz fragments and black, altered biotite and hornblende. The highly altered type has a clayey odor and is extremely friable.

Thin sections made from samples taken from the areas of "fresh" quartz-monzonite showed a holocrystalline rock with partially formed crystals (hypidiomorphic texture). The essential minerals proved to be quartz, orthoclase and a plagioclase which the extinction angle indicated to be oligocene. Of the total composition about twenty percent is quartz, and about sixty percent is equally divided between orthoclase and the plagioclase. The remainder of the rock is composed of ferro-magnesian minerals, mainly hornblende and biotite, and minor accessories.

Most abundant of the dark minerals is hornblende which shows marked pleochroism in shades of green. Also exhibiting strong pleochroism is biotite that is present in a ratio of one to three of hornblende; the two make up most of the remaining twenty percent of the total composition. Observed associated with the ferro-magnesian minerals are opaque grains of magnetite, and occasional euhedral grains of apatite and zircon. Thus, the above described rock is truly a quartz-monzonite.

As a whole the "fresh" quartz-monzonite shows little alteration. The hornblende, however, has changed over to epidote to a consider-degree; and the plagioclase is beginning to alter to sericite. Samples of this rock from the highly altered areas are masses of kaolin and sericite derived from the feldspars, and chlorite and iron oxide derived from the biotite and hornblende. This effect is due to hydrothermal alteration in conjunction with the mineral-ization of the many milky quartz veins cutting through the quartz-monzonite, and the alteration is not believed to be associated with the deposition of fluorite.

The quartz-monzonite contains numerous, small, basic inclusions which after weathering protrude as nodes from the oxidized surfaces. Beneath the darkened surface the minerals have been bleached and are yellow due to iron stains. Commonly an angular sand is the product of the weathering of the quartz-monzonite, and in most cases the clay minerals have been carried away, but instances were noted where massive boulders lay buried in material resulting from their own decomposition.

Aplite--The aplite in the area studied occurs both in dikes and irregular bodies. A body of this type of rock shown in the north central part of the geologic map of the region of the fluorite deposit is an irregular mass, and no sharp contact between the quartz-monzonite and the aplite was noted, although it may be present. Aplite and the quartz-monzonite may grade into one another, but in the case of the dikes a sharp division between the two was observed. Dikes of this acidic type rock were viewed cutting through the quartz-monzonite in many places, and the width ranged from a few inches up to three feet.

To the unaided eye the aplite is a white to pinkish colored rock with a sugary texture--it looks very much like an arkose.

Figure 3. Photomicrograph of aplite showing graphic intergrowth. X 20

In some places this rock was blotched with faint green stains due probably to the decomposition of biotite into chlorite. So widely scattered and in such small grains is the biotite that it is seldom noted in a hand specimen.

Petrographic examination of the aplite discloses that of the total composition forty percent is quartz, and nearly all of the remainder is feldspar. Both plagioclase and orthoclase are present; the plagioclase is albite and is present in about one-sixth the amount of orthoclase. The only accessory minerals observed were widely scattered, minute grains of biotite and occasionally a grain of tourmaline.

The texture of the aplite is holocrystalline and hypidiomorphic. One of the slides showed an excellent example of graphic intergrowth, apparently resulting from the filling of a vug (See Figure 3); and in places the aplite appeared to grade into a micropegmatite.

As was the case with the quartz-monzonite, the plagioclase appeared to alter readily to sericite while the orthoclase showed more resistance to alteration. The biotite alters to chlorite or to masses of ocher. Little hydrothermal effect near the quartz veins was observed.

Very resistant to weathering is the aplite. The irregular masses form rounded surfaces and gentle slopes while the dikes tend to weather into slabs. Where small dikes are found high on a hillside, pink aplite slabs cover the area below the dikes, a fact which misleads one as to the size of the aplite body. Ultimately with the decomposition of the feldspars to clay a very coarse sand with grains about the size of rice is produced.

Alteration

Although hydrothermal alteration and weathering of the igneous rocks has been mentioned, another type of alteration is conspicuous, that of silicification. The silicification appears to be gradational and is most intense near the breccia zone in which fluorite fragments are found. Silica in the form of chalcedony apparently has been introduced into the wall rocks at the same time the breccia was silicified, and in addition some hematite was carried by the hydrothermal solutions. Introduced hematite is most noticeable on the bold hill south of U.S. Highway 10 where the red color is due as much to hematite as to red andesite, and it is possible that the hematite in the hydrothermal waters may have been derived from the andesite since the hematite is found only where andesite is most prominent. Instances were also noted where the red iron oxide was present in the cryptocrystalline quartz to the extent that jasper was formed.

Structure of the Area

Previously it was stated that the fluorite deposit is on the contact of the Boulder batholith. That contact is not the original igneous contact but is a contact developed by faulting, whereby the Cretaceous andesites of the downthrown block are butted against the plutonic rocks of the batholith on the upthrown member of the fault.

To start at the beginning, however, the many, milky quartz veins in the eastern part of the area mapped should be considered. The vein system there exposed corresponds roughly to that of the well known Butte district where four major fissure systems of differing strike are pronounced. Oldest of the Butte fissures is the east-west striking system. Several veins trending in that direction were observed in the area in question. It was on one of those veins (at Shaft No. 1) that pyrite was found, the only mineralization other than barren quartz observed in any of the milky quartz veins in the region. Corresponding to the northwest-southeast series of Butte are many prominent outcrops, and one northeast-southwest striking fissure was found. The fourth main system at Butte is the one striking north-south, and a fissure of that type was observed in the mapped area.

Some time after the formation of the milky quartz vein system, chalcedonic quartz was precipitated in a fissure, designated as No. 1, striking N 20° W; and in a nearly parallel fissure, shown as No. 2, at a later date the banded fluorite was deposited. See Figure 4. The fluorite is later than the chalcedony because the fluorite vein cuts through No. 1 fissure in Pit 2 marked on the geologic map of the area. A series of east-west faults,

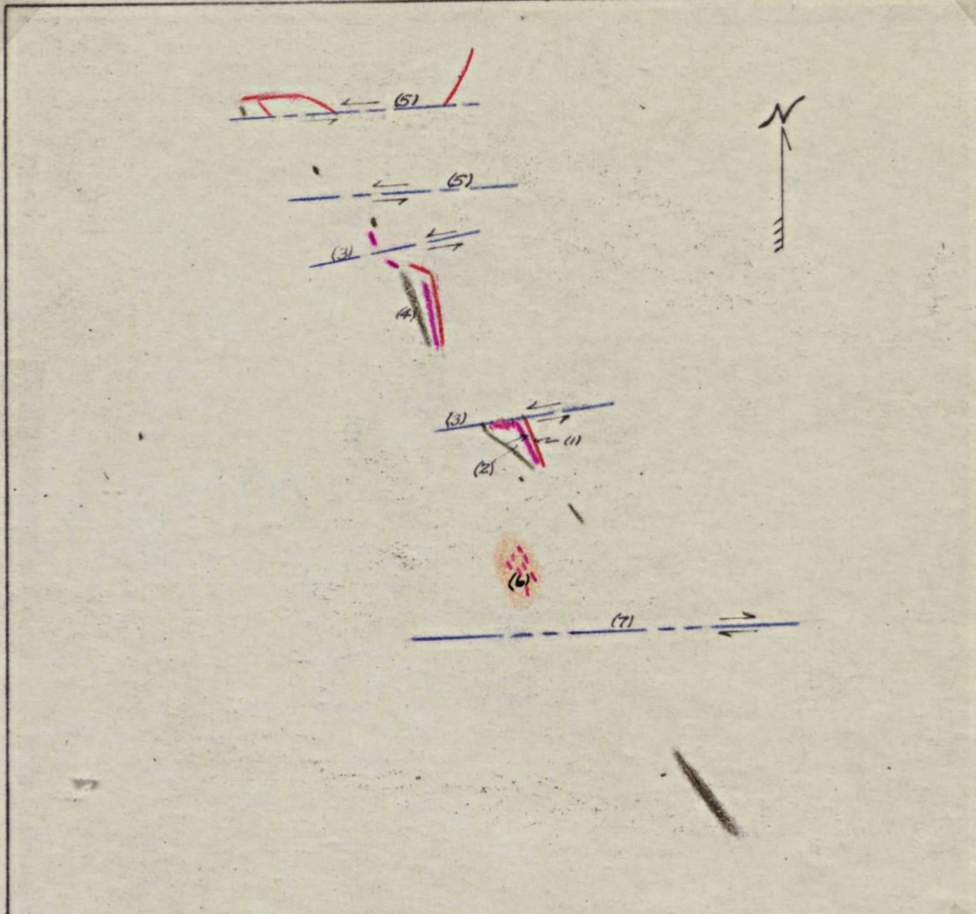


FIGURE 4. IDEALIZED STRUCTURAL PATTERN

indicated by No. 3, then shattered the older chalcedony and fluorite veins. Broken fragments of the banded fluorite and the chalcedony are found in a fissure trending east and west north of Pit 2.

Marked by the silicified breccia and gouge is the fourth fault, designated as No. 4. Its strike is N 20° W and its dip, 65° W; but both vary considerably locally. The differential elevation between the andesite and the igneous body is probably due to this fault--one of considerable size as the width of the breccia zone indicates. The breccia is composed of angular fragments of aplite, quartz-monzonite, andesite and widely scattered, rounded pieces of fluorite; the whole is cemented by chalcedony. In a hand specimen the gouge resembles rhyolite, but thin sections showed that the apparent phenocrysts are remnants of quartz grains formerly contained in fragments of igneous rocks. The quartz grains have been eaten into and replaced by the chalcedonic bearing solution that silicified the zone as is shown in Figure 5. Rounded

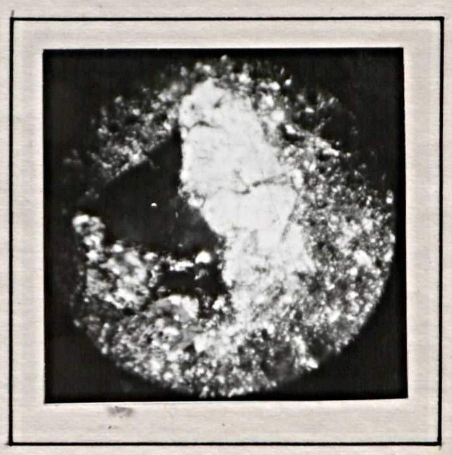


Figure 5. Photomicrograph of silicified gouge showing quartz (black) and orthoclase (white) being replaced by chalcedony (mottled gray and white)

fragments of fluorite in the breccia are good evidence of the older age of the fluorite vein, as is the fact that the breccia forms the hypotenuse of a triangular set of fissures, one leg of which is the unshattered fluorite vein and the other leg, a shattered zone containing fragments of the fluorite vein.

Since portions of the breccia zone now lie en echelon another period of faulting, indicated by No. 5, is evidenced.

In all probability the precipitation of the gray-white fluorite followed next in the sequence. This type of fluorite is found cementing another breccia, No. 6, the origin of which cannot be definitely stated due to insufficient exposures. It may be a talus breccia or a breccia resulting from slump of the fault breccia produced by fault No. 4. Slickensides in breccia No. 6

indicate a fault, the large size of the fragments and the type of cement indicate a talus breccia; but large breccia fragments might result adjacent to the fissure on the downthrow block of a normal fault due to drag or slump as shown in Figure 6. It is also conceivable that slickensides might be formed on two large fragments of the breccia that move differentially. The writer believes the origin of breccia No. 6 to be due to faulting.

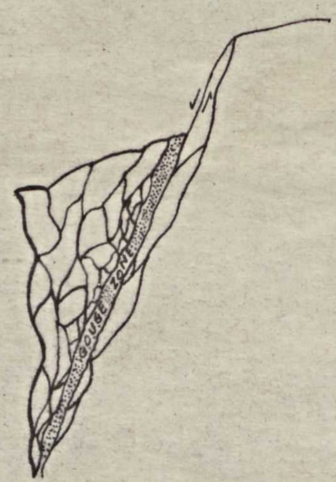
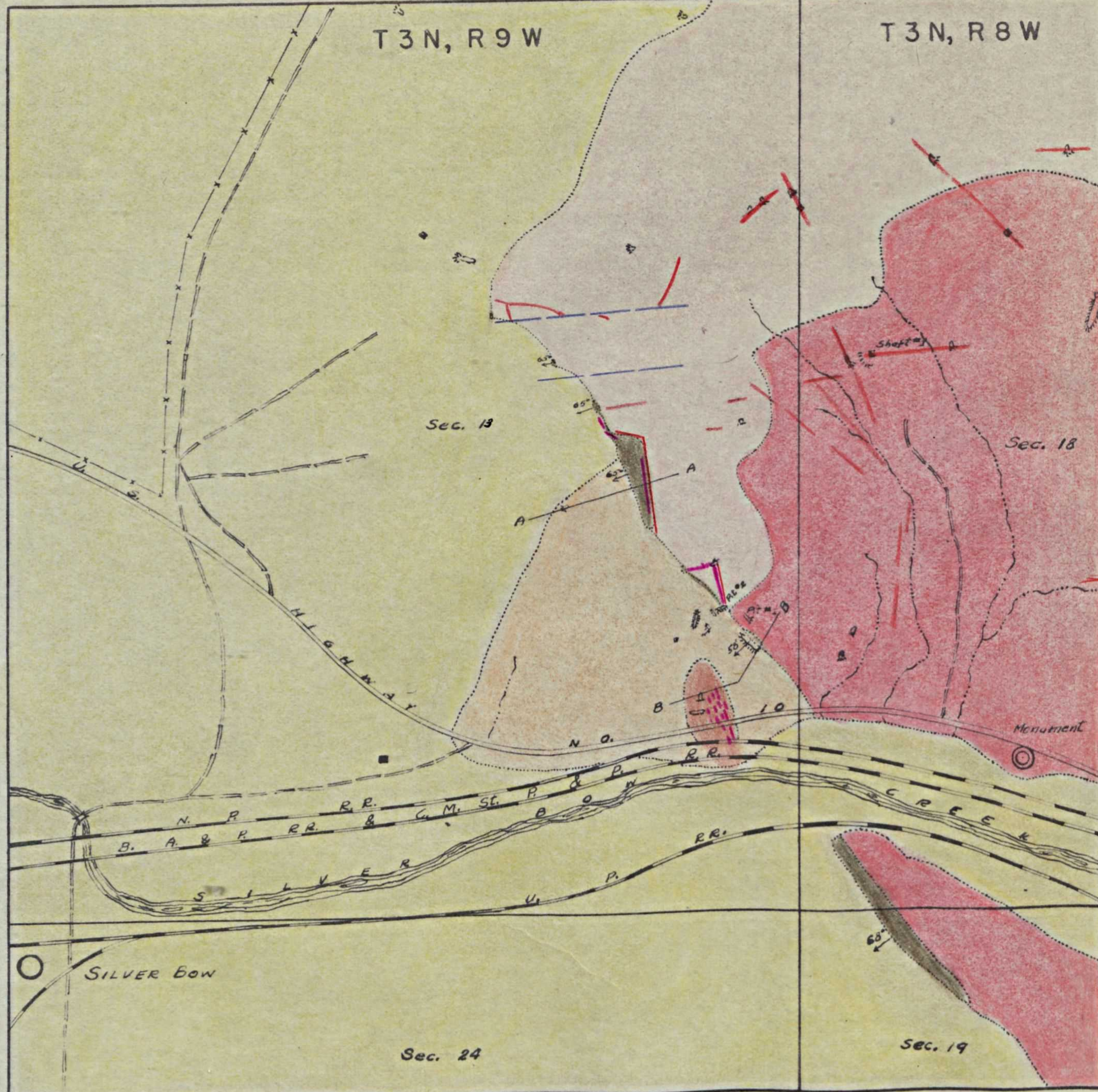


FIGURE 6. Diagramatic sketch of probable brecciation relative to a fault

Earth deformation ended with what the writer believes to be another east-west fault, No. 7, along the bottom lands of Silver Bow Creek. The slip of that fault is much greater than in the case of previous east-west fissuring, and it is in the opposite direction. Outcrops of No 4 breccia north and south of Silver Bow Creek lie en echelon, and in each case the breccia-cementing fluorite lies to the west of No. 4 breccia. It is, therefore, probable that this last mentioned fault occurred after deposition of the whitish-gray, breccia-cementing fluorite.



LEGEND

Quaternary alluvium and lake beds

Quartz-monzonite

Aplite

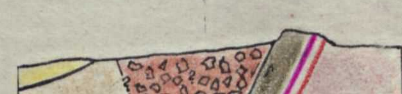
Andesite

Breccia

Fluorite vein

Quartz veins

Fault



CROSS-SECTION A-A

CROSS-SECTION B-B

(Horizontal scale in cross-sections is twice exaggerated)

GEOLOGIC MAP OF AREA OF FLUORITE DEPOSIT NEAR SILVER BOW, MONTANA

Scale 1" = 500'

Drawn by C.V. Campbell
Montana School of Mines
Butte, Montana
January, 1944

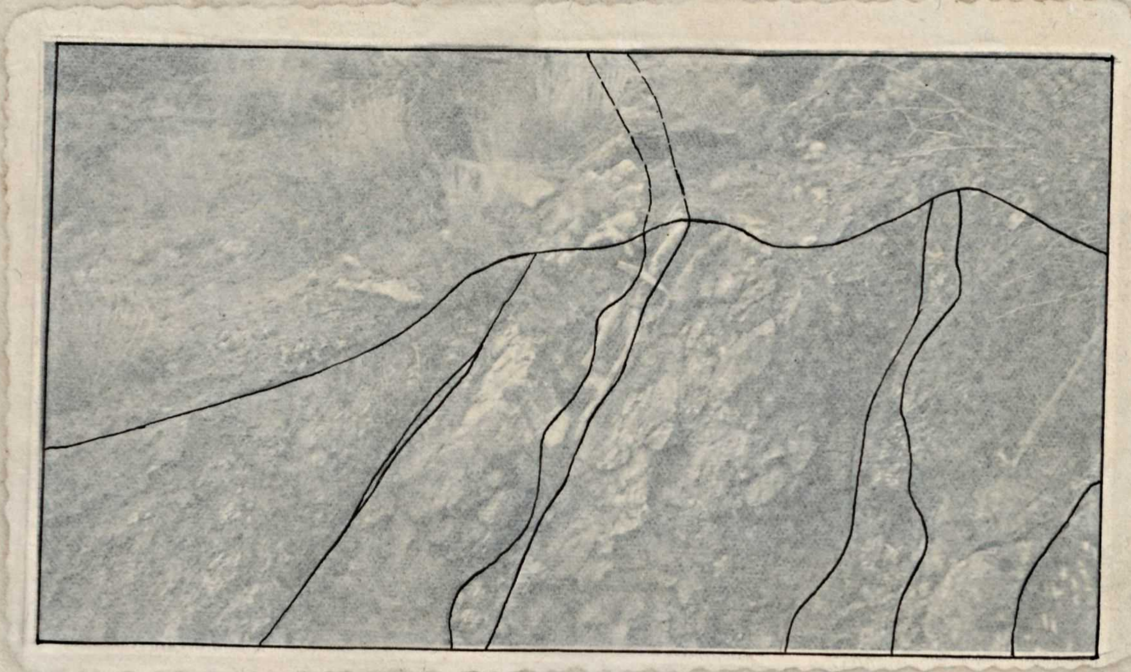
THE FLUORITE DEPOSIT

The fluorite deposit discussed in this paper is associated with igneous rocks, both plutonic and volcanic and has the two modes of occurrence described below. Structural and textural features of the veins indicate that the deposit probably is of the epithermal type; the origin appears to be precipitation from hot spring solutions.

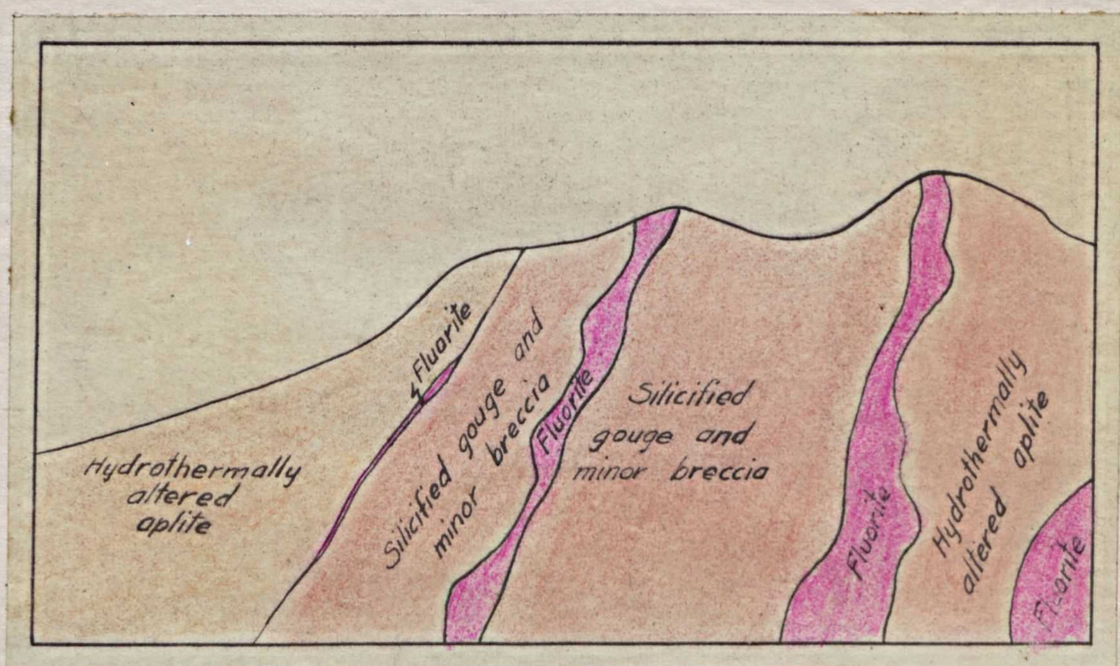
Character and Distribution of the Fluorite

Two occurrences of fluorite were found in the area surveyed. The first is a fissure filling of banded vein-type fluorite which is well exposed in Pit 2, shown on Plate V, where the strike is N 20° W and the dip is 65° W. In this pit three distinct strands of fluorite are found; the widths of the two larger ones average three inches while a half inch stringer is found on the hanging wall of the fissure. The two feet between the larger veins is made up of silicified gouge composed mainly of aplite fragments, and in the one-foot distance between the hanging wall stringer and the westernmost of the larger bands a similar material is found.

From Pit 2 the two larger veins can be traced northward along the strike for one-hundred and fifty feet where an east-west fault shattered the vein. Along that fissure for eighty feet to the west shattered fragments of fluorite occur. The fluorite vein is next picked up two hundred feet to the north where it lies a few feet east of the silicified breccia zone, No. 4 of Figure 4. Only one of the larger veins is visible there since the westernmost one was probably ruptured by further faulting; somewhat rounded

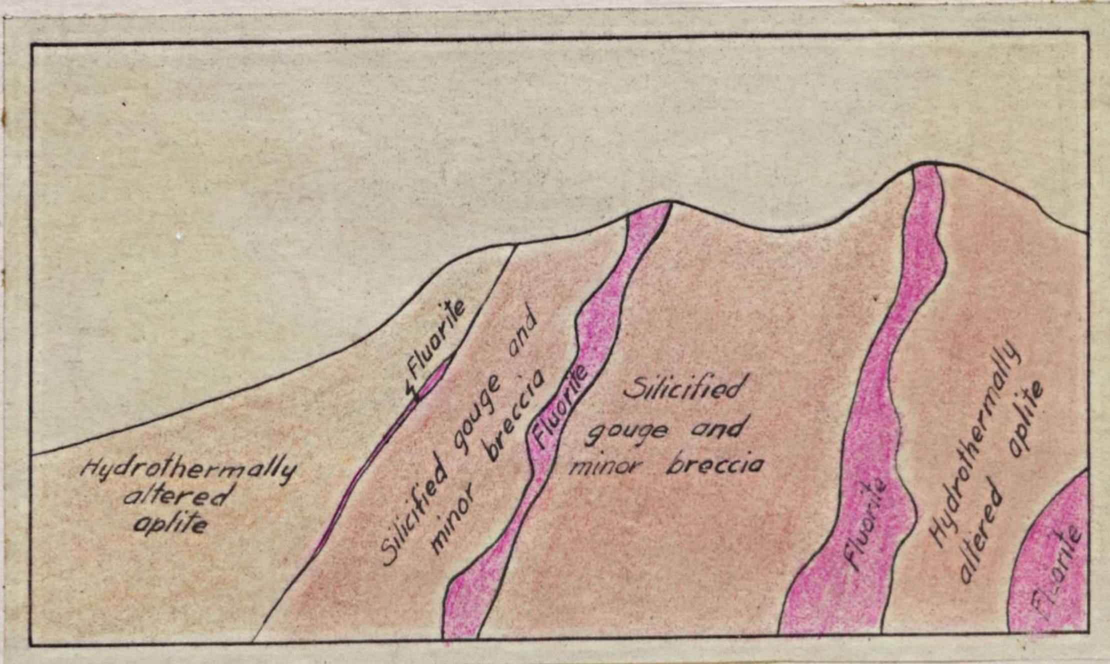


A. View of working face in prospect pit shown in Plate III-A
The fluorite vein is in the foreground.



B. Sketch showing relationship of fluorite, silicified
gouge and altered aplite

A. View of working face in prospect pit shown in Plate III-A
The fluorite vein is in the foreground.



B. Sketch showing relationship of fluorite, silicified gouge and altered aplite fluorite pebbles are found incorporated in the silicified breccia previously discussed. The strike and dip are the same as in Pit 2.

After continuing for about two hundred feet more in a northerly direction, the vein is again faulted by an east-west trending fissure. The last remnant of that fluorite vein is found just north of this fault, but fluorite occurs on the west side of the silicified breccia outcrop instead of on the east side. Further tracing of the veins northward is prevented by a covering of alluvium.

The second type of fluorite occurs as a cement to a very loose breccia. North of U.S. Highway 10 a small area of this breccia is shown on the geologic map of the Silver Bow area, and it is exposed in the road cut. South of the highway is alluvium and Silver Bow Creek which prevents further observation of this body, but more of the same type of fluorite was observed south of Silver Bow Creek where it appears again to lie west of the silicified breccia zone.

Mineralogy and Paragenesis

Associated with the coarse-grained, banded vein-type fluorite is chalcedony with a few grains of pyrite. Chalcedony was the only mineral found with the fluorite that cements the loose breccia. Secondary minerals found with the fluorite in the fissure fillings are limonite resulting from the weathering of pyrite and dendritic coating probably of pyrolusite along crystal faces.

<u>Fluorite</u>--The first or vein-type of fluorite occurs in coarsely crystalline, columnar bands separated by partings made up mainly of chalcedony. Good cubical crystals are found facing into vugs, but they are small as are the vugs.

The color of those bands varies and is not always uniform;

some crystals are translucent and others, transparent. Colors observed included colorless, white, gray, pale yellow, pink, rose-red, lavender, purple, bluish-purple, black and tints of green. The darkest colored bands are found closest to the footwall of the fissure, and the intensity of the color decreases toward the hanging wall. Exactly what causes the varying colors in the fluorite is not definitely known other than that it might be due to impurities in the mineral. Weathering appears to bleach the color from the fluorite, and the result is a dull, milky-white fluorite along the outcrop of the vein.

The second or breccia-cement type of fluorite is not directly associated with the vein-type of fluorite. It is generally in medium to fine crystals--at times forming drusy surfaces--which are whitish-gray. Good crystals of cubic habit may be found facing into cavities between breccia fragments that are not completely filled.

Chalcedony--Chalcedony occurs with both types of fluorite. The partings separating the bands of fluorite in the fissure filling are made up of over ninety-five percent cryptocrystalline quartz which under crossed nicols of a petrographic microscope shows as a mottled mass of microscopic crystals. To the unaided eye the chalcedony resembles unglazed procelain.

The chalcedony associated with the whitish-gray fluorite occurs predominantly as a thin band dividing the fluorite from the breccia fragments. In both instances the color of the chalcedony varies from snow white to buff, and ground waters carrying iron in solution have colored that material yellowish- orange.

Pyrite and limonite--Only one specimen of many examined showed unaltered pyrite that was visible to the unaided eye, and then only one crystal was found in fluorite adjacent to the wall rock. Minute scattered blobs of limonite in the chalcedony, however, indicate the former presence of pyrite crystals.

Paragenesis--The banding in the vein-type of fluorite indicates cycles of deposition. First a thin coating of chalcedony, which contains minute specks of pyrite, precipitated on the walls of the fissure; and then fluorite crystals formed over the chalcedonic coating. This cycle was repeated until the fissure was filled.

In the case of the breccia-cement type of fluorite the sequence of deposition is the same as above except that the cycle does not repeat. It is possible, however, that the chalcedony enclosing the breccia fragments was precipitated during the silicification of breccia zone No. 4 and was not a component of the solution from which the fluorite deposited.

That the mineralized solution contained a strong acid or base is indicated at the contact between the fluorite and the cryptocrystalline quartz. There the solution from which the fluorite precipitated etched and partially dissolved or replaced the underlying chalcedony.

Structural and Textural Features of the Veins

Most striking is the crustified and symetrical banding, pictured in Plate VI-A, which is a conspicuous feature of the vein fluorite. Each fluorite band, composed of large, close-packed crystals of fluorite, is separated by a band of cryptocrystalline quartz; minute crystals of pyrite are also found associated with

Plate VI

A. Left. Vein-type fluorite showing crustified and symetrical banding X 4/10

B. Right. Shows vein-type fluorite partially enclosing a fragment of country rock. X 4/10

C. Left. Breccia-cement type of fluorite showing fluorite (white) filling in around andesite fragments (black).

D. Right. Breccia-cement type of fluorite. Note the crystalline fluorite enclosing the andesite fragment in the lower left. Drusy surface in the center was the interior of a vug.

the chalcedony. Vugs of varying size, both in the fluorite and the chalcedony, indicate deposition in openings; and silicified and partially replaced inclusions of country rock were enveloped in the ascending solutions, as shown in Plate VI-B.

The veins are not of uniform width horizontally or vertically along their extent. In places the fissure fillings pinch to nothing and in other places swell to several inches in width due to irregularities of the walls. In all instances the contact between the vein material and the wall rock shows "frozen" walls. The three parallel strands previously described are all found in a single fault gouge zone and may be the result of splitting of a larger vein at depth.

The whitish-gray, breccia-cementing fluorite tends to form drusy surfaces on the fragments of andesite and in the fractures of a loose, unconsolidated breccia composed of andesite fragments. Many instances were noted, however, where the crystals grew to such a size that they completely filled the fractures. See Plate VI-C and D. Other cases were observed where cavities in the fluorite were formed due to incomplete filling of fractures.

Mode of Origin

General and textural features of epigenetic deposits discussed by Lindgren[1] include:

1-Conspicuous crustification and comb structure

2-Irregular walls with vein matter "frozen" to the walls

3-Splitting, chambering, and brecciation of veins

4-Short, irregular, complex vein systems

5-Delicate and symetrical banding due to crustification

[1]Mineral Deposits, 4th edition, 1933, p. 445 and p. 170

6-Fine-granular texture with crustified and drusy forms

7-Fine-grained quartz fillings, ranging to cryptocrystalline and chalcedonic near the surface

8-Sulfides in small crystals or anhedrons

9-Primary brecciated structure

10-Secondary crushing and brecciation of primary minerals

11-Banding or sheeted structures resulting from the development of shear planes in the old filling

In addition to the above list Grout[1] has listed the following suggestive characteristics of shallow hydrothermal alteration:

1-Extensive silicification by chalcedony near the vein

2-Association with weathered rocks or those that form at shallow depths

3-Deposition of ores in or very near fractures

4-Gangue minerals: andularia, alunite, zeolites, chalcedony and others

5-Ore minerals: cinnabar, stibnite, native copper, tellurides and others

With the exception of secondary crushing, brecciation and sheeting and the presence of the more definite characteristic minerals, practically all of these criteria were noted. No trace of any diagnostic high temperature or intermediate vein-type minerals was found. Consequently, the deposit must be a shallow type deposit. The vein fluorite has been eroded to some depth, but the breccia-cementing fluorite has been little eroded and is exposed at what is probably the original surface where precipitation occurred.

[1]Grout, Petrography and Petrology, 1932, p. 426

The fluorite was probably derived from a magmatic source, and was carried upward by ascending hot spring solutions through fissures where deposition occurred. That the magma contained fluorine is evidenced by the presence of the fluorine-bearing minerals, apatite, tourmaline, micas and hornblende, in the igneous rocks of the Boulder batholith; and the fluorite is found in and associated with those igneous rocks. Possibly segregation of an acid phase of the magma occurred at depth where the gases given off were trapped under pressure. The irregular bodies and dikes of aplite are indications that such an acidic phase separated out of the magma. Faulting in the vicinity of such a segregation would provide a path along which the compressed gases might escape.

Fluorine along with water vapor could be components of the gaseous segregation; silica could also be contained. The fluorine may have been present as hydrofluoric acid or as sodium or potassium fluoride in an aqueous solution formed by the condensation of the steam; in either case, according to Mendeleef and as further explained by Fohs[1] and Bishof[2], from that solution calcium fluoride (fluorite) would precipitate when it came in contact with either calcium silicate or calcium carbonate. Calcium silicate is abundant in the feldspars making up the rocks of the region, and calcium carbonate is a common product of surface weathering.

Deposition of fluorite from hot springs is not unknown, and many hot springs are known to carry fluorine. The best example of such a deposit is recorded by W.H. Emmons and E.S. Larsen[3] at

[1]Fohs, F.J., Fluorspar deposits of Kentucky, Ky. Geol. Surv. Bull. 9, 1907, p. 62
[2]Bischof, G., Chemische Geologie, vol. 1, 2nd ed., Bonn., 1863, pp. 48 and 54
[3]Econ. Geol., 8, 1913, pp. 235-46

Wagon Wheel Gap, Colorado. There a fluorite vein, if projected along the strike, would bisect a deposit of travertine at the mouth of a flowing hot spring and pass close to a second. Another hot spring at Ojo Caliente, New Mexico is reported to carry 0.19 percent fluorine, and fluorite veins are associated with the spring deposits farther up the valley[4].

[2]Lindgren, W., Econ. Geol., 5, 1910, pp. 22-27

ECONOMIC CONSIDERATIONS

The successful exploitation of a fluorite deposit, or any ore deposit, depends primarily on the grade of the ore, the tonnage available for mining, the price and the demand. Anyone of the above that is unfavorable prohibits profitable operations; and, hence, these factors should be carefully considered.

Commercial fluorspar is divided into three basic grades. "Acid grade" spar, which must contain 98 to 98.5 percent CaF_2 and less than 1.0 to 1.5 percent silica, is used to make hydrofluoric acid and is the purest market grade of spar. "Glass and enamel grade" spar is used in making glass, enamels, ferro-silicon and ferro-manganese, and contains 95 to 96 percent CaF_2 with siliceous impurities. The minimum requirements for commercial fluorspars include the "gravel spars" which contain a minimum of 85 percent CaF_2 and a maximum of 5 percent siliceous impurities.

Fluorite of satisfactory grade could be produced from the Silver Bow fluorspar by simple crushing and gravity concentration or at a somewhat higher cost by hand sorting or flotation concentration.

It is not possible at present to make a reliable estimate of the tonnage available, because of the lack of development work. Veins and thin strands of veins of fluorite up to six inches in width may be traced on the surface, however, for 150 feet. Beyond, the vein structure continues, but the fluorite is present as scattered vein segments from one-half inch to perhaps six inches in thickness. In a vertical dimension the fluorite is exposed near the top of a hill and in a pit approximately 40 feet lower in elevation. Furthermore, in a six foot face in the pit three strands of fluorite included in the vein structure range in thickness from about six inches to less than one inch,.or disappear. This indicates that a continuous sheet of fluorite of a definite width is not present in the vein structure, but that the thickness present is extremely variable. It is estimated that within the six-foot width of vein structure observed in the pit the amount of fluorite is from 4 to 6 percent of the vein matter. Furthermore, if the deposit is the result of hot spring action, as the author believes, it would not be expected to continue to a very great depth.

The amount of breccia-cement fluorite present is even more difficult to estimate because of a lack of development and exposures. Individual boulders of cemented breccia may contain 5 to 10 percent fluorite; but these, no doubt, are the richest grade material. Moreover, the width of breccia containing fluorite is not known. Since fluorite resists weathering, it would seem probable that if a large body of this type of material were present, it would show in outcrop.

The wartime demand for fluorite has raised the price of fluorspar sixty percent above the normal price of about $20 per short ton of "gravel spar" delivered to eastern steel mills. Considerable variation in value of the different grades of spar exists; however, acid grade spar normally brings about $28 per short ton delivered.

Since the chief use of fluorspar is for flux in the open hearth steel furnaces, the markets are necessarily in the east, in Colorado or in California where steel mills are located. Hence, any Montana fluorspar would have to compete with local fluorspar production (Illinois-Kentucky, Colorado, Nevada) under a handicap of three times or more the freight rate charged the local producers. The average freight rate per ton to eastern points approaches $10.

To summarize, the grade of the fluorspar would seem to be satisfactory; but present development on the fluorite veins and the erratic surface exposures indicate an insufficient tonnage for commercial exploitation. Such would be the case even if low mining costs would compensate for the handicap of the high freight rate.